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Piotr Arendarski
Łukasz Postek

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Piotr Arendarski
University of Warsaw
Faculty of Economic Sciences
e-mail: parendarski @wne.uw.edu.pl

Łukasz Postek
University of Warsaw
Faculty of Economic Sciences
e-mail: lpostek@wne.uw.edu.pl
Economic Institute, National Bank of Poland
e-mail: lukasz.postek@nbp.pl

Abstract

This paper explores cointegration among three of the most popular agriculture soft commodities (corn, soya and wheat) and its potential usefulness for dynamic asset allocation strategies. Johansen tests indicate that natural logarithms of weekly prices of corn, soya and wheat futures are cointegrated and two cointegrating vectors exist. Formal tests show that the estimated long-run relationship is stable even beyond the estimation sample. We use obtained results to create simple trading rules and verify their profitability. The trading strategies' risk-adjusted abnormal returns look to be significant based on the Sharpe ratio criterion and they are low correlated with the stock market.

Keywords:
cointegration, soft commodities, trading rule

JEL:
C58, G11

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1. Introduction

Cointegration is a useful method for examining the relationship among financial time series. Engle and Granger (1987) demonstrate that, if a vector of time series is cointegrated, the long-run parameters can be estimated directly without specifying the dynamics because, in statistical terms, the long-run parameter estimates converge to their true values more quickly than those operating on stationary variables. This discovery has accelerated techniques for exploring long-run relationships between time series.

The concept of applying cointegration to cope with market efficiency is not new and there is a long-lasting discussion regarding the existence of cointegration among agricultural commodities. The general conclusion is that commodities that are based on the same underlying product, such as soya bean crush and soya bean oil, should be cointegrated. However, the evidence for this seems rather weak, and the academic argument that related commodities such as different types of metals should be cointegrated is even more difficult to justify empirically (Alexander, 2001). Brenner and Kroner (1995) present a useful survey of the literature in this area and conclude that the idiosyncratic behavior of carry costs makes it very difficult to use ECMs in commodity markets. Booth and Ciner (2001) investigate four soft commodities: corn, red bean, soybean and sugar. They find that the daily prices of the four commodity futures traded on the Tokyo Grain Exchange (TGE) do not move together in the long run. However, taken by themselves, TGE corn and soybean prices are cointegrated. This relationship seems to be consistent with agricultural commodity futures' long-run co-movements being in response to common economic fundamentals and non-herding behaviour attributed to traders. Bhar and Hamori (2006) perform similar research to Booth and Ciner (2001), using more recent data to confirm their findings. They use daily data from 1994 to 2003 and find that the formal tests indicate no cointegration among the time series of agricultural prices for the total sample period.

On the other hand, there is some academic research that suggests existing long-term relationships among agricultural commodities. Pindyck and Rotemberg (1990) perform tests confirming that the prices of several commodities such as wheat, cotton, copper, gold, crude oil, lumber and cocoa have a persistent tendency to move together. As an explanation, they suggest that commodity price movements are partially the result of 'herd behaviour.' In line with that findings, Malliaris and Urrutia (1996) empirically test the linkages among the futures prices of six soft commodities traded at the Chicago Board of Trade (CBOT): corn, wheat, oats, soybean, soybean meal, and soybean oil. Their data comprise daily observations collected during a sample period from 1981 to 1991 and they find a strong long-term relationship among the six commodity futures contracts.

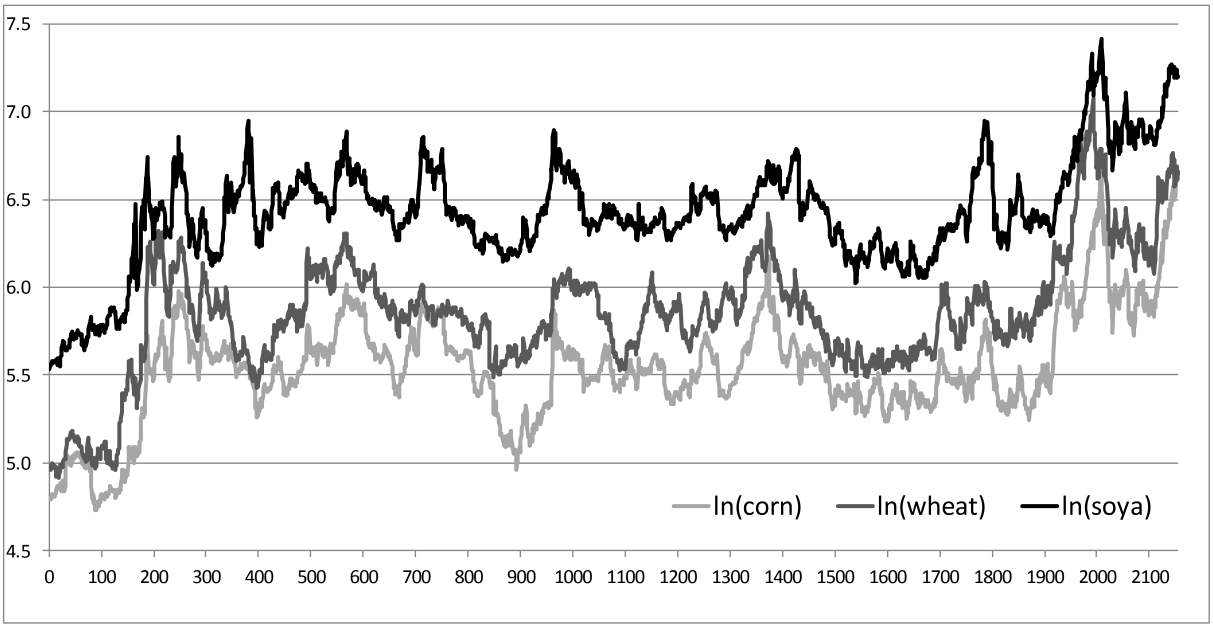
The above findings show that there is no agreement regarding soft commodities' long-run dependency' but even if that is the case it is unlikely that it could be exploited to obtain abnormal returns. It is worth noting, however, that most research deals with daily data, which could be hard to analyze in terms of cointegration because of the irregular structure of the time series (weekends, holidays etc.). In contrary to this common practice, in this paper we analyze the weekly futures prices of three of the most popular agriculture soft commodities: corn, soya and wheat. Our aim is to examine the long-term linkages between weekly close prices of these commodities. Finally, we apply simple cointegration-based investment strategies exploiting short-term deviations among the agricultural commodities to achieve abnormal risk-adjusted profits.

This paper is structured as follows. In Section 2 we present data and methodology. In Section 3 we perform analysis of cointegration and show that long-run relationship among the prices of these commodities holds and is stable even beyond the estimation sample. In Section 4 we utilize these findings and create simple trading rules that seem to give abnormal returns that are low correlated with stock market.

2. Data and methodology

We analyze the natural logarithms of weekly futures prices of soft commodities: corn, soya and wheat. The data come from the Chicago Mercantile Exchange and cover the period of 1/9/1970 to 4/22/2011, i.e. 2155 observations. We set the first 1500 observations as an estimation sample, and the last 655 observations as a test sample. The data are plotted in Figure 1.

Figure 1. Natural logarithms of weekly prices of corn, soya, and wheat



Source: Chicago Mercantile Exchange

In the first step we apply basic unit root tests to verify whether all the analyzed time series are I(1) and whether any cointegrating relationship may exist. Next we estimate an unrestricted VAR model and choose the appropriate number of lags relying on lag length criteria. For chosen number of lags we carry out Johansen trace and maximum eigenvalue tests (Johansen, 1991, 1995) allowing for different sets of deterministic trend assumptions. Subsequently, we estimate cointegrating relationships and investigate whether they hold in a test sample, i.e. beyond an estimation sample. Finally, we use the obtained results to create simple trading rules and verify their profitability.

3. Analysis of cointegration

Because we analyze logarithms of the prices of food commodities (corn, soya and wheat), we should expect (from an economic point of view) that our series are I(1) and that they may contain linear deterministic trend due to inflation. The results of the unit root tests shown in Table 1 confirm that series are I(1), but they are somewhat ambiguous if we consider deterministic trend assumptions. While carrying out Johansen tests we later show that the analyzed time series must indeed contain a linear trend.

Table 1. The results of unit root tests for analyzed time series (1% significance level)

	H_0: non-stationarity Augmented Dickey-Fuller	H_0: stationarity Kwiatkowski-Phillips-Schmidt-Shin
	ln(corn)	
conclusion	*at least I(1)*	*at least I(1)*
selected model	*with intercept only*	*with linear trend and intercept*
	ln(soya)	
conclusion	*at least I(1)*	*at least I(1)*
selected model	*with intercept only*	*with linear trend and intercept*
	ln(wheat)	
conclusion	*at least I(1)*	*at least I(1)*
selected model	*with intercept only*	*with linear trend and intercept*
	H_0: non-stationarity Augmented Dickey-Fuller	H_0: non-stationarity Phillips-Peron*
	Δln(corn)	
conclusion	*I(0)*	*I(0)*
selected model	*no intercept or trend*	*no intercept or trend*
	Δln(soya)	
conclusion	*I(0)*	*I(0)*
selected model	*no intercept or trend*	*no intercept or trend*
	Δln(wheat)	
conclusion	*I(0)*	*I(0)*
selected model	*no intercept or trend*	*no intercept or trend*

* This time the Kwiatkowski-Phillips-Schmidt-Shin test is not carried out, since it requires including intercept in the test equation.

Firstly we estimate an unrestricted VAR model. Using lag length criteria (see Table 2), we set four lags in the model. In our case this choice is insensitive to intercept and linear trend inclusions.

Table 2. Lag length criteria for unrestricted VAR model

	sequential modified LR test statistic (5% level)	final prediction error	Akaike information criterion	Schwarz information criterion	Hannan-Quinn information criterion
lag selection	4	4	4	1	3

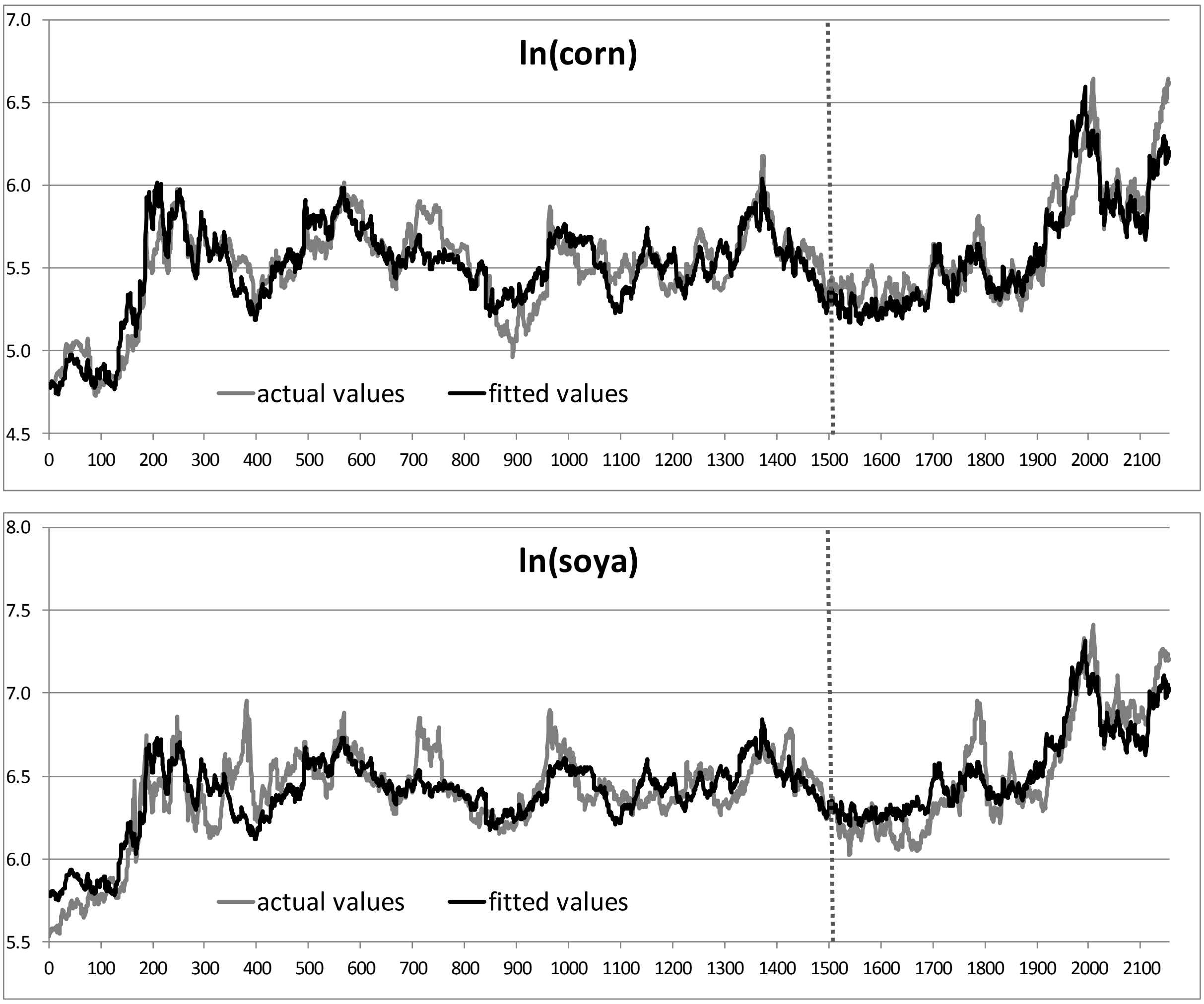
Based on these results we carry out Johansen tests allowing for different sets of deterministic trend assumptions. Since we analyze three time series, only zero, one or two cointegrating relationships may exist. As shown in Table 3, only two sets of assumptions give reliable results. Otherwise the model is misspecified, and the tests showing three cointegrating relationships are not valid. Because we deal with series that have a non-zero mean, we know that also the first set of assumptions is incorrect. Therefore there must be a linear trend in the data and the estimated two cointegrating relationships should include an intercept and a linear trend.

Table 3. The results of the Johansen tests

deterministic trend in data	none	none	linear	linear	quadratic
cointegrating equations	no intercept no trend	intercept no trend	intercept no trend	intercept trend	intercept trend
trace	2	3	3	2	3
maximum eigenvalue	2	3	3	2	3

Relying on the abovementioned findings, we estimate two long-run relationship vectors. Since numerical values are not very informative we present estimated cointegrating relationships in Figure 2.

Figure 2. Estimated long-run relationships vs. real data



Though we are not interested in the error correction mechanism itself, and we do not show its estimates, the mechanism works as proposed by the theory, i.e. deviations from long-run relationships are gradually revised. This can also be easily observed in Figure 2. Moreover, it seems that the estimated long-run relationships hold in a test sample as well. These findings are formally confirmed by unit root tests for the "residuals" for the test sample (see Table 4).

Table 4. The results of unit root tests for "residuals" computed for a test sample (1% significance level)

	H_0: non-stationarity Augmented Dickey-Fuller	H_0: non-stationarity Phillips-Peron*
	ln(corn)_residuals	
conclusion	*I(0)*	*I(0)*
selected model	*no intercept or trend*	*no intercept or trend*
	ln(soya)_residuals	
conclusion	*I(0)*	*I(0)*
selected model	*no intercept or trend*	*no intercept or trend*

* This time the Kwiatkowski-Phillips-Schmidt-Shin test is not carried out, since it requires including intercept in the test equation.

One may expect that the stability of the estimated long-run relationship may be somehow utilized to create simple trading rules. In the next section we propose such rules and investigate their profitability.

4. Analysis of trading rule

The main purpose of the trading part of our research is to create a monthly rebalanced portfolio of soft commodities for the test sample. The general idea is to use "residuals" as an indicator of directional trading and then calculate fitted values of corn and soya based on wheat prices and cointegrated vectors. The trading assumptions are as follows:

– one contract of soya, corn or wheat has the same dollar value

– transaction costs are 0,1% per contract

Firstly, we calculate the deviation between actual values and fitted values. If the actual values of corn or soya are greater than the fitted ones, then we buy wheat, sell corn or soya and hold for four weeks. After four weeks we rebalance portfolio. Since we are not able to use the vectors as weights (because there is trend parameter and intercept), we use another technique for determining weights to keep the portfolio market neutral which is *minimum variance hedge ratio h* (Johnson, 1960) calculated as:

$$h = \rho \frac{\sigma_i}{\sigma_j}$$

where:

ρ – correlation coefficient between returns of *i* and *j* commodity

σ_i – standard deviation of returns of *i* commodity

σ_j – standard deviation of returns of *j* commodity

In this way we construct several strategies which are presented in Table 5.

Table 5. Trading strategies

Mhvr corn	use of minimum variance hedge ratio
Mhvr soya	use of minimum variance hedge ratio
Weighted	use *mhvr corn* and *mhvr soya* strategy, equal weights

Mhvr corn trading strategy is calculated as follows. We use the correlation coefficient between the returns of corn and wheat and multiply it by the relation between the standard deviation of returns of corn and the standard deviation of returns of wheat. We use the rolling *minimum variance hedge ratio,* where the roll period is 20. Then, for example, if the deviation between ln(corn) and the fitted value of ln(corn) is greater than 0, we sell 1 contract of soya and buy a value of contract of wheat which is determined by the *minimum variance hedge ratio.* Transaction is made every four weeks. Weights of corn and soya are updated, determined by new value of *minimum variance hedge ratio and* deviation between ln(corn) and fitted value of ln(corn). *Mhvr soya* trading strategy is calculated in the same way.

Figure 3 and Table 6 present the cumulative results for all strategies. As we can see there is a persistent upward trend among the strategies. The strategies start to gain positive returns after some time, from the beginning year 2002. This phenomenon is not surprising. We can notice that during the first part of the test sample period the prices of both ln(corn) and ln(soya) are quite stable. What is interesting is that, during the financial crisis (2007–2009) the strategies still perform very well.

Figure 3. Cumulative percentage returns in the test sample (1=100%)

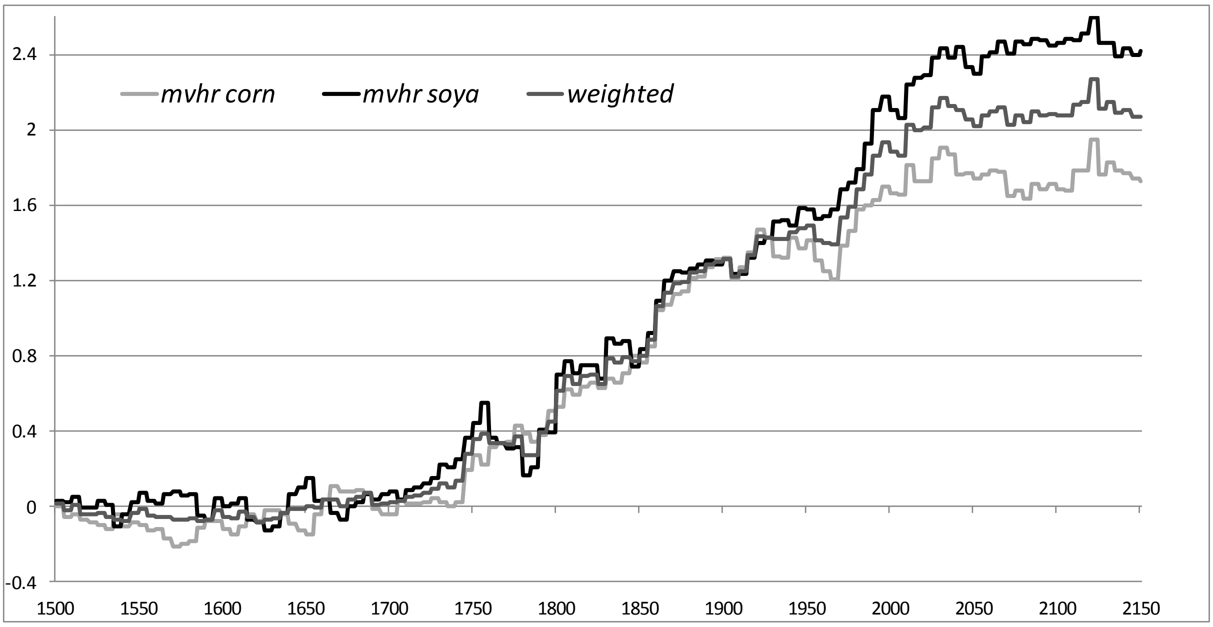
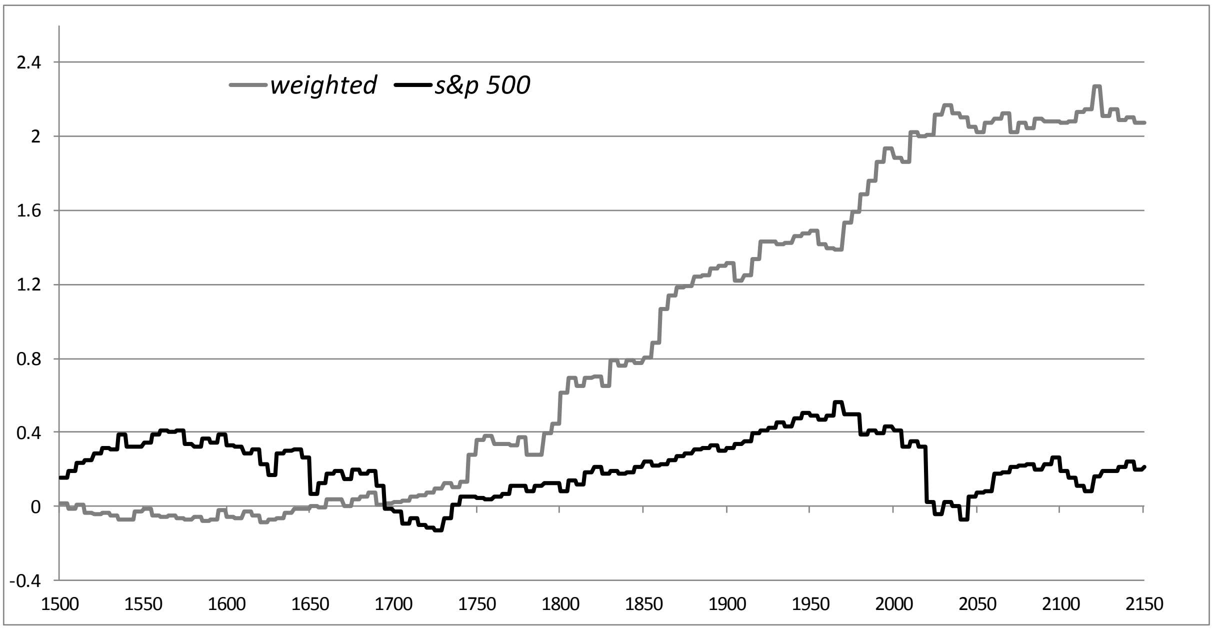


Table 6. Summary statistics of investment strategies out-of-sample

	mhvr		*weighted*
	corn	soya	
Mean net return (annual)	15.8%	22.1%	18.0%
St. dev/annual	2.10%	2.21%	1.80%
Sharpe Ratio	5.2	7.72	7.2
Profitable months no.	71	82	81
Profitable months %	54.2%	62.6%	61.8%
Trades no.	131	131	131
Rebalance no.	24	19	24

If we look at the results, it is evident that 'weighted' strategy performs very well in terms of the Sharpe ratio and standard deviation. It would be worthwhile to compare this strategy to a benchmark, however, that is difficult to determine in such complex conditions. For simplicity we compare the *weighted* strategy to S&P 500. Figure 4 illustrated the comparison of the *weighted* strategy and S&P 500 in terms of cumulative percentage returns.

Figure 4. Cumulative percentage returns of *weighted* strategy and S&P 500 (1=100%)



The correlation coefficient between both strategies (0.11) is very low and statistically insignificant, so the diversification of the portfolio using this kind of strategy looks very promising.

5. Summary

The main aim of this paper was to explore cointegration among three of the most popular agriculture soft commodities (corn, soya and wheat) and its potential usefulness for dynamic asset allocation strategies. We find that natural logarithms of the prices of corn, soya and wheat are cointegrated and that the estimated long-run relationships are stable even beyond the estimation sample. These findings underlie simple trading rules we propose. The Sharpe ratio for *weighted* strategy based on *minimum variance hedge ratio* looks very promising. What is more, there is a low correlation between this strategy and the stock market (S&P 500). This implies that using the proposed strategy to lower portfolio risk might be a reasonable solution.

Undoubtedly, there is need for further research in that field. Our results are clearly preliminary ones and the *weighted* strategy we propose is just one of many possible trading rules in that case. It would be useful to optimize our strategy and examine how changing the underlying assumptions (e.g. the frequency of rebalancing the portfolio, the roll period) may improve its performance. Another interesting idea might be to analyze how different market volatility regimes influence the effectiveness of the strategy.

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Faculty of Economic Sciences
University of Warsaw
44/50 Długa St.
00-241 Warsaw
www.wne.uw.edu.pl